Weed Risk Assessment for *Geranium lucidum* L. (Geraniaceae) – Shining cranesbill

Maryland Department of Agriculture

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Version 1

Infestation of *Geranium lucidum* forming an almost continuous carpet in an Oregon White Oak riparian habitat (source: Bruce Newhouse, Bugwood.org; LaForest 2013). Inset: Habit and flower of *G. lucidum* (source: Bruce Newhouse, Bugwood.org; LaForest 2013).

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Introduction The Maryland Department of Agriculture regulates terrestrial ornamental invasive plants under the authority of Md. AGRICULTURE Code Ann. § 9.5-101 et seq. Invasive Plant Prevention and Control. An invasive plant is defined as a terrestrial plant species that a) did not evolve in the State, and b) if introduced within the State, will cause or is likely to cause, as determined by the Secretary: economic, ecological, environmental harm or harm to human health.

Maryland's Invasive Plant Advisory Committee (IPAC) was established by legislative mandate in October 2011. The IPAC's primary responsibility is to advise the Secretary of Agriculture on regulating the sale of invasive plants, and on preventing them from entering Maryland or from spreading further in the state. IPAC evaluates the risk potential of plants already present in Maryland, newly detected in the Maryland or the United States, those proposed for import, and those emerging as weeds elsewhere in the world.

IPAC evaluates the potential invasiveness of plants using the weed risk assessment (WRA) process developed by the Plant Protection and Quarantine (PPQ) Program of the US Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) (Koop et al. 2012). PPQ's risk model uses information about a species' biological traits and behavior to evaluate its risk potential (Koop et al. 2012).

Because the PPQ WRA model is geographically and climatically neutral, it can be used to evaluate the baseline invasive/weed potential of any plant species for the entire United States, or for any specific region in the United States. In the PPQ process, the geographic potential of the species is evaluated separately so that risk managers can make decisions appropriate for their regions. With respect to Maryland's evaluation process, we use PPQ's Geographic Information System overlays of climate to evaluate the potential for a plant to establish and grow in Maryland. The PPQ weed risk assessment also uses a stochastic simulation to evaluate how the uncertainty associated with the assessments affects the model's predictions. Detailed information on the PPQ WRA process is available in the document, *Guidelines for the USDA-APHIS-PPQ Weed Risk Assessment Process* (APHIS PPQ 2015), which is available upon request.

IPAC uses a second tool, the Maryland Filter, to assign plant species that score as highly invasive either Tier 1 or Tier 2 status. Maryland regulations define Tier 1 plants as "invasive plant species that cause or are likely to cause severe harm within the State" and Tier 2 plants as "invasive plant species that cause or are likely to cause substantial negative impact within the State." The Maryland Filter considers the actual and potential distribution of the species in Maryland, its threat to threatened and endangered ecosystems and species in the state, the difficulty of control of the species, and whether added propagule pressure would be likely to increase its persistence and spread significantly. IPAC then

recommends regulations to reduce the risk of the Tiered invasive plants in Maryland.

	***Geranium lucidum* L. – Shining cranesbill**
Species Information	Family: Geraniaceae
	Synonyms: *Geranium laevigatum* Royle (eFloras 2013).
	Common names: Shining cranesbill, Shining crane's bill (ARS 2015).
	Botanical description: *Geranium lucidum* is an upright annual herb with dark pink flowers. Beaked seed pods hold many seeds (eFloras 2013).
	Initiation: Maryland evaluated this species because it was ranked as High Risk by APHIS-PPQ, has been sold in the United States as an ornamental species, and is not currently present in Maryland. The New Pest Advisory Group of APHIS-PPQ evaluated *Geranium lucidum* in 2007 and recommended a policy of non-reportable/non-actionable, partly because the states of California, Oregon, and Washington expressed no interest in establishing official control programs (NPAG 2007). Recently though, the King County Noxious Weed Program of Washington State featured this species in its monthly newsletter (Shaw 2013) and reported that it is regulated as a State Noxious Weed in Washington (NWCB 2013) and Oregon (ODA 2013). Because of this change in state policy, the APHIS Plant Epidemiology and Risk Analysis Laboratory (PERAL) Weed Team decided to evaluate this species. Because *G. lucidum* may also be a weed in Canada, we conducted this risk assessment in collaboration with the Canadian Food Inspection Agency (CFIA).
	Foreign distribution: This species is native to Europe, northern Africa, the Middle East, Caucasus, central Asia, and temperate Himalaya (Aedo et al. 1998; eFloras 2013). It has been introduced in Australia (Randall 2007) and New Zealand (Howell and Sawyer 2006; Tomson 1922).
	Canada distribution and status: This species was first collected in Canada in 1982 from a Vancouver Island roadside (Univ. of Alberta 2013). In 2010, it was found southeast of Vancouver Island on a grassy roadside on Salt Spring Island (Klinkenberg 2013). It is not clear if *G. lucidum* is casual or fully naturalized in British Columbia. It is not listed in online Canadian plant databases (Brouillet et al. 2013; Government of Canada 2013), suggesting it is not fully naturalized. During a recent visit to the Salt Spring Island site, investigators did not find any *G. lucidum* plants (Clements 2013). The status of the plants on Vancouver Island has not been verified.
	U.S. distribution and status: *Geranium lucidum* is naturalized in 13 counties in Oregon, five in Washington and two in California (CISEH 2013; Univ. of California 2013). It is a Class A State Noxious Weed in Washington, so public and private landowners are required to control and eradicate the species (NWCB 2013). It was first collected in 1971 in the United States from a cow pasture in Oregon (Dennehy et al. 2011; OSU Herbarium 2006).

Geranium lucidum is reported to be a cultivation escape (DiTomaso and Healy 2007). We think it is cultivated to a very limited extent because we found it being sold by only one, specialized U.S. nursery (Anonymous 2013a). Seeds are also available online from the United Kingdom (Plant World Seeds 2013). This species may have been intentionally introduced into the United States because of its use as an herbal plant (ODA 2013; PFAF 2013).

WRA area[1]: Entire United States and Canada, including U.S. territories.

Summary Statement

Geranium lucidum ranks as a high risk species because of its rapid spread and ability to compete with native vegetation. It is not currently found in Maryland but has the potential to establish widely in the state if it were to be introduced. Because of its potential distribution and likelihood of affecting threatened and endangered species in Maryland, it is ranked as Tier 1.

1. *Geranium lucidum* analysis

Establishment/Spread Potential

Geranium lucidum is a shade-tolerant winter annual that has become naturalized in the Western United States and has been spreading since it was first detected in 1971 (Dennehy et al. 2011; OSU Herbarium 2006). This species is self-compatible (Yeo 2004), reproduces by seed (Dennehy et al. 2011; Van Assche and Vandelook 2006), and forms dense carpets of seedlings in invaded habitats (Dennehy et al. 2011; Taylor 2006). Seeds are dispersed by the explosive recoiling of the awn (Aedo 2000; Dennehy et al. 2011; Yeo 2004), and even in still air the seeds can travel up to 20 feet (Salisbury 1961). People also disperse seeds accidentally (Alverson 2007; Anonymous 2013b; Dennehy et al. 2011): *G. lucidum* spread from Oregon to Washington in contaminated nursery plants (Anonymous 2013b; Dennehy et al. 2011). It may also spread as a contaminant of agricultural seed (Salisbury 1961).Contributing to its success as an invasive species, *G. lucidum* forms a seed bank that persists for more than a year (Taylor 2006; Van Assche and Vandelook 2006). We had a less than average level of uncertainty with this risk element.

Risk score = 17 Uncertainty index = 0.11

Impact Potential

Geranium lucidum is primarily a concern to natural systems because it dominates habitat understories and excludes native herbaceous species (Alverson 2007; Dennehy et al. 2011; FBP 2006; ODA 2013). Although it is currently not a direct threat to threatened and endangered species, it could make habitat restoration for rare species difficult (Alverson 2007). In its native range in Europe, it is considered a garden weed (FNI, 2013; Salisbury 1961). In the United States *G. lucidum* is considered a "major threat to the integrity of oak woodland habitats" (Dennehy et al. 2011). This species is being actively

[1] "WRA area" is the area in relation to which the weed risk assessment is conducted [definition modified from that for "PRA area" (IPPC, 2012).

managed in Oregon (Dennehy et al. 2011; Taylor 2006) and the Nature Conservancy in Oregon is trying to eradicate it from some preserves (Alverson 2007). Washington state is also trying to eradicate it (NWCB 2013). Because *G. lucidum* moves with nursery stock (Anonymous 2013b; Dennehy et al. 2011), it may impact trade if the importing country or region regulates the weed. We had an average amount of uncertainty.
Risk score = 2.5 Uncertainty index = 0.17

Geographic Potential Based on three climatic variables, we estimate that about 54 percent of the United States and 4 percent of Canada is suitable for the establishment of *G. lucidum* (Fig. 1). This predicted distribution is based on the species' known distribution elsewhere in the world and includes point-referenced localities and areas of occurrence. The map for *G. lucidum* represents the joint distribution of Plant Hardiness Zones 6-9, areas with 10-100+ inches (25-254+ cm) of annual precipitation, and the following Köppen-Geiger climate classes: Steppe, Mediterranean, Humid subtropical, Marine west coast, Humid continental warm summers, Humid continental cool summers,Ssubarctic, and Tundra.

The area of the United States shown to be climatically suitable (Fig. 1) is likely overestimated since our analysis considered only three climatic variables. Other environmental variables, such as soil and habitat type, may further limit the areas in which this species is likely to establish. In its native range, *G. lucidum* occurs in seashores, stony hillsides, rocks, hedges, and walls (Dunn 1905; Presland 2008; Stace 2010). It can also grow in mountainous regions as high as 2000–3000 meters in elevation (eFloras 2013). In the United States, it grows in oak woodlands, dry conifer forests, riparian forests, roadsides, and pastures (Dennehy et al. 2011; OSU Herbarium 2006). It generally appears to be more invasive in moist habitats (Shaw 2013).

Entry Potential We did not assess the entry potential of *Geranium lucidum* because it is already present in the United States (CISEH 2013; Univ. of California\, 2013) and Canada (Klinkenberg 2013; Univ. of Alberta 2013).

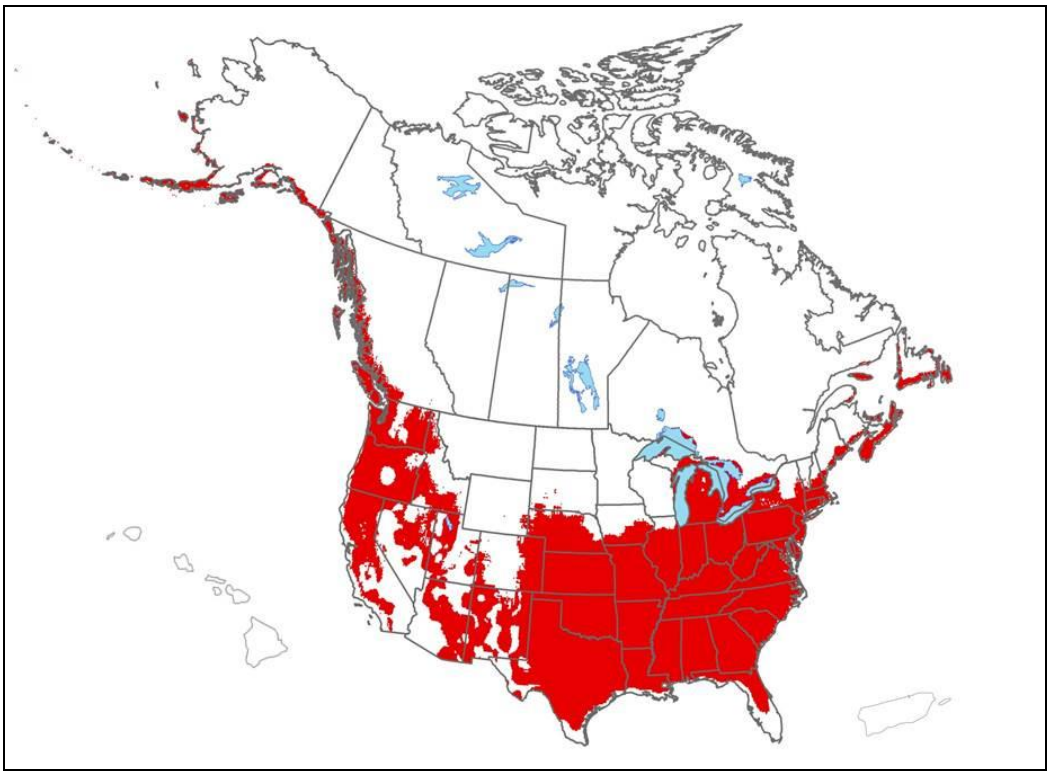

Figure 1. Predicted distribution of *Geranium lucidum* in the United States and Canada. Map insets for Hawaii and Puerto Rico are not to scale.

2. Results

Model Probabilities: P(Major Invader) = 79.8%
P(Minor Invader) = 19.4%
P(Non-Invader) = 0.8%

Risk Result = High Risk

Secondary Screening = Not Applicable

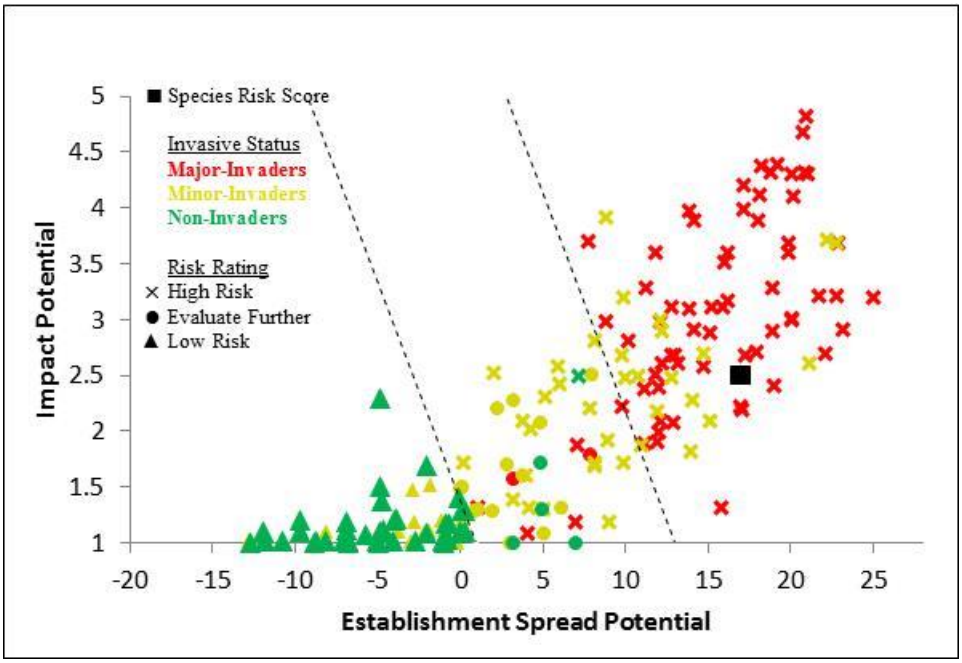

Figure 2. *Geranium lucidum* risk score (black box) relative to the risk scores of species used to develop and validate the PPQ WRA model (other symbols). See Appendix A for the complete assessment.

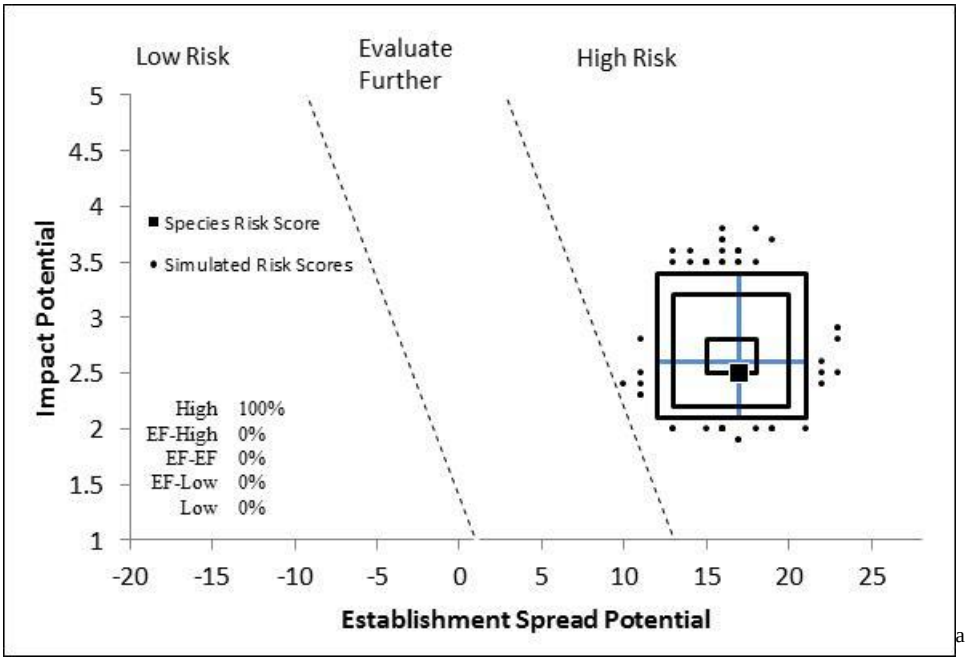

Figure 3. Model simulation results (N=5,000) for uncertainty around the risk score for *Geranium lucidum*. The blue "+" symbol represents the medians of the simulated outcomes. The smallest box contains 50 percent of the outcomes, the second 95 percent, and the largest 99 percent.

3. Discussion

The result of the weed risk assessment for *Geranium lucidum* is High Risk (Fig. 2). Our uncertainty analysis supports this conclusion as all of the simulated risk scores also resulted in conclusions of High Risk (Fig. 3). Our model indicates *G. lucidum* has an 80 percent likelihood of becoming a major invader, and its invasive behavior in the Pacific Northwest coast supports this idea. Since it was first detected in Oregon in 1971, it has rapidly spread throughout the region. Natural dispersal, unintentional dispersal by people, and dispersal in the nursery trade have contributed to its spread.

"Once fully established, *Geranium lucidum* is virtually impossible to eliminate from a site due to its rapid rate of increase, high plant density, persistent seed bank, and difficulty of implementing management treatments without causing collateral damage to associated native herbaceous species" (Dennehy et al. 2011). A natural-areas manager believes it cannot be eradicated from heavily infested areas in Oregon, but keeping it from spreading to new areas may be possible using Early Detection and Rapid Response activities (Alverson 2007).

Geranium lucidum ranks as Tier 1 in the Maryland Filter because it has the potential to be widely distributed and to negatively affect Maryland threatened and endangered species and ecosystems.

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Appendix A. Weed risk assessment for *Geranium lucidum* L. (Geraniaceae). The following information was obtained from the original risk assessment for this species (full responses and all guidance), which is available upon request. We modified the information here to fit on the page.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ESTABLISHMENT/SPREAD POTENTIAL			
ES-1 (Status/invasiveness outside its native range)	f - negl	5	This species is broadly native from Europe and northern Africa through the Middle East to Nepal, Pakistan, and northwestern India (NGRP 2013). Introduced to Australia (Randall 2007). Introduced to New Zealand as early as 1903 (Tomson 1922) and currently casual (Howell and Sawyer 2006; Sykes 1982). Has been collected twice from roadside habitats in Canada (Vancouver Island and Salt Spring Island) (Klinkenberg 2013; Univ. of Alberta 2013). Naturalized in the United States (Aedo 2000) and spreading (Univ. of California 2006). "It was first collected in Oregon in Yamhill County in 1971. It has now spread throughout the Willamette Valley, and is beginning to spread south into the Umpqua and Rogue Valleys, and north into Washington. As of 2010, populations have been documented in Washington in Clark, Thurston, King, and Skagit Counties" (Dennehy et al. 2011). Alternate answers for the Monte Carlo simulation are both "e."
ES-2 (Is the species highly domesticated)	n - negl	0	This species is cultivated to a limited extent (Anonymous 2013a; Backyard Gardener 2013); however, we found no evidence of domestication or breeding to reduce weed-associated traits. Seeds are available online from the United Kingdom (Plant World Seeds 2013).
ES-3 (Weedy congeners)	y - negl	1	*Geranium molle*, *G. simense*, and *G. tuberosum* are principal weeds in one country each (Holm et al. 1991). The similar species *G. robertianum* is causing a decline in native species in the understory of Pacific Northwest habitats (Boersma et al. 2006).
ES-4 (Shade tolerant at some stage of its life cycle)	y - negl	1	Occurs in seashores and stony hillsides (Dunn 1905). In the United States, "*Geranium lucidum* is most abundant in open shade, especially in oak woodlands, but also in riparian and bottomland forests that are dominated by hardwoods" (Alverson 2007). Grows well in shady areas of Oregon (FBP 2006; OSU Herbarium 2006), California (Univ. of California 2006), and Washington (WTU 2006). Generally grows in shade (Dennehy et al. 2011). It is interesting that it is reported to be mostly shade intolerant in Europe, but in the United States it is shade tolerant (ODA 2013). Perhaps there are other ecological factors affecting its distribution. Regardless, there is negligible uncertainty as it grows in the shade in the United States.
ES-5 (Climbing or smothering growth form)	n - negl	0	Plants are terrestrial herbs 5-45 cm tall (Aedo 2000).
ES-6 (Forms dense thickets)	y - negl	2	Forms dense populations (Dennehy et al. 2011; Taylor 2006). Seeds germinate in mass in the fall, producing carpets of seedlings (Dennehy et al. 2011).
ES-7 (Aquatic)	n - negl	0	Plant is not an aquatic species; rather, it is a terrestrial herb (Aedo 2000; Yeo 2004).
ES-8 (Grass)	n - negl	0	Species is in the Geraniaceae (NGRP 2013).
ES-9 (Nitrogen-fixing woody	n - negl	0	The Geraniaceae (NGR, 2013), is not a plant family known to

Question ID	Answer - Uncertainty	Score	Notes (and references)
plant)			contain nitrogen-fixing species (Martin and Dowd 1990).
ES-10 (Does it produce viable seeds or spores)	y - negl	1	Reproduces by seed (Anonymous 2013b; Dennehy et al. 2011; Van Assche and Vandelook 2006).
ES-11 (Self-compatible or apomictic)	y - low	1	"[T]he flowers automatically self, with the stigmas diverging slightly before the flower opens and the dehisced anthers pushing their pollen up between them" (Yeo 2004). The very similar congener *G. robertianum* is also self-compatible (Boersma et al. 2006).
ES-12 (Requires special pollinators)	? - max		Unknown. Two sources indicated it is pollinated by insects (Anonymous 2013b; PFAF 2013), but they don't report what kind of insects. Another source indicates that small bees with long tongues are attracted to the nectar (Yeo 2004), but this does not confirm pollination.
ES-13 (Minimum generation time)	b - negl	1	Plant is an annual (Aedo 2000; eFloras 2013; Yeo 2004) or biennial (DiTomaso and Healy 2007). A winter annual (Van Assche and Vandelook 2006). Plants normally germinate in autumn, but they can also germinate in spring, at which point they will have an abbreviated lifecycle where flowers appear before the cotyledons wither and die (Yeo 2004); this reference does not consider plant lifecycle or minimum generation time. Alternate answers for the Monte Carlo simulation are "c" and "a."
ES-14 (Prolific reproduction)	? - max	0	Unknown. There was not enough information in the literature to either directly or indirectly answer this question. Although online pictures of high population densities in the Pacific Northwest coast of the United States would suggest that prolific reproduction is possible, we did not see any pictures of high densities of flowering and fruiting plants. There are multiple species of cranesbill geraniums. For most species in cornfields, seed production ranges between 300 and 400 per plant (Salisbury 1961).
ES-15 (Propagules likely to be dispersed unintentionally by people)	y - negl	1	Dispersed in yard trash that is dumped alongside roads (Alverson 2007). It may also be dispersed in mud attached to vehicles and people (Alverson 2007). Seeds disperse on feet of people (Dennehy et al. 2011), but no specific evidence provided. Seeds disperse on shoes and vehicles (Anonymous 2013b). This species was detected on Salt Spring Island near a clump of cut stems (Klinkenberg 2013), but it unclear if it arrived in that location via plant trash.
ES-16 (Propagules likely to disperse in trade as contaminants or hitchhikers)	y - negl	2	It spread from Oregon to Washington in contaminated nursery plants (Anonymous 2013b; Dennehy et al. 2011). It may also be spread as an impurity in agricultural seed (Salisbury 1961).
ES-17 (Number of natural dispersal vectors)	1	-2	For ES17a through ES17e: Fruit in the cranesbill geraniums consist of five single-seed carpels (Salisbury 1961). In *G. lucidum*, "Seed 2 mm long, oblong, reddish, glabrous, lower end with a black protuberance" (eFloras 2013). In Pakistan, seeds are oblong, approximately 1-1.2 mm by 0.9-1.0 mm (Ather et al. 2012). As a member of the subgenus *Robertium*, the mericarps with their single seed each are actively discharged by the explosive recoiling of the awn (Aedo 2000; Dennehy et al. 2011; Yeo 2004). Even in still air, the seeds can be dispersed up to 20 feet away (Salisbury 1961).
ES-17a (Wind dispersal)	n - low		No evidence and does not seem likely.

Question ID	Answer - Uncertainty	Score	Notes (and references)
ES-17b (Water dispersal)	n - low		No evidence and does not seem likely.
ES-17c (Bird dispersal)	n - low		No evidence and does not seem likely.
ES-17d (Animal external dispersal)	y - mod		It may be dispersed on mud attached to wild and domesticated animals (Alverson 2007). The pattern of population dispersion suggests it is dispersed by animals and humans (Taylor 2006), but this doesn't distinguish between internal and external dispersal. Primary long-distance dispersal mechanism is on the feet of deer or livestock (Dennehy et al. 2011), but no specific evidence provided. Dispersed by wildlife (presumably externally), but supporting information not given (ODA, 2013). Answering "yes" with moderate uncertainty based on the number of anecdotal comments. Seeds of the invasive congener *G. robertianum* have a sticky fiber at one end that allows them to stick to animals, leaves, or other surfaces (Boersma et al. 2006). *Geranium lucidum* may have a similar dispersal trait.
ES-17e (Animal internal dispersal)	n - mod		No evidence. Using moderate uncertainty because it is unknown if seeds may be consumed by browsing animals.
ES-18 (Evidence that a persistent (>1yr) propagule bank (seed bank) is formed)	y - negl	1	Freshly matured seeds of *G. lucidum* have water impermeable seed coats (Van Assche and Vandelook 2006). Seed burial experiments showed that seeds remain viable for more than one year and need a period of desiccation to break dormancy (Van Assche and Vandelook 2006). Experience from managers controlling populations suggests it has a long-term seed bank (Taylor 2006).
ES-19 (Tolerates/benefits from mutilation, cultivation or fire)	? - max	0	Unknown.
ES-20 (Is resistant to some herbicides or has the potential to become resistant)	n - low	0	No evidence (Heap 2013). "*G*[*eranium*] *lucidum* can be treated with either glyphosate or triclopyr" (Dennehy et al. 2011). "All the cranesbills are relatively resistant to selective herbicides," but some control can be achieved if applied at the early seedling stage (Salisbury 1961).
ES-21 (Number of cold hardiness zones suitable for its survival)	4	0	
ES-22 (Number of climate types suitable for its survival)	8	2	
ES-23 (Number of precipitation bands suitable for its survival)	10	1	
IMPACT POTENTIAL			
General Impacts			
Imp-G1 (Allelopathic)	? - max		Unknown. It may have an allelopathic effect based on how it smothers other herbaceous vegetation (Alverson 2007). "The extreme abundance of *G. lucidum* at some sites, to the exclusion of other vegetation, suggests an allelopathic effect" (Dennehy et al. 2011). Answering "unknown" because neither of these two sources provides any evidence.
Imp-G2 (Parasitic)	n - negl	0	No evidence. This species is not a member of a plant family known to contain parasitic plants (Heide-Jorgensen 2008; Nickrent 2009).
Impacts to Natural Systems			
Imp-N1 (Change ecosystem processes and parameters that	n - mod	0	No evidence.

Question ID	Answer - Uncertainty	Score	Notes (and references)
affect other species)			
Imp-N2 (Change community structure)	y - high	0.2	We did not find any evidence this species changes the physical structure of habitats by creating or eliminating a layer. However, based on the guidance, because it dominates habitat understories (Alverson 2007; ODA 2013) and thereby eliminates their structural diversity, we are answering "yes," but with high uncertainty. Also see images on bugwood.org.
Imp-N3 (Change community composition)	y - negl	0.2	Forms extensive pure stands (FBP 2006). Displaces natives and probably inhibits recruitment of native forbs (Dennehy et al. 2011). "Pushes out" early spring wildflowers (ODA 2013). Appear to suppress the growth of native herbaceous species (Alverson 2007).
Imp-N4 (Is it likely to affect federal Threatened and Endangered species)	y - mod	0.1	Because this species forms extensive stands that outcompete early spring wildflowers (ODA 2013), it is likely to impact understory threatened and endangered species. In Oregon, it generally wouldn't impact threatened and endangered species because those species, tend to occur in prairie habitats; however, *G. lucidum* could make it extremely difficult to restore habitat for these rare species (Alverson 2007).
Imp-N5 (Is it likely to affect any globally outstanding ecoregions)	y - high		This species is considered a "major threat to the integrity of oak woodland habitats" in the United States (Dennehy et al. 2011). Because of its ability to form extensive pure stands (FBP 2006), it is likely to affected globally outstanding ecoregions along the west coast of North America.
Imp-N6 (Weed status in natural systems)	c - negl	0.6	It is a major weed of natural systems (Dennehy et al. 2011). It can invade and overwhelm high quality native habitat, including woodlands and prairies (Anonymous 2013b). The Nature Conservancy in Oregon has been trying to eradicate it from some of their preserves (Alverson 2007). It is a specific management target in Washington and Oregon in oak woodland, prairie, and savanna habitats within the Willamette Valley-Puget Trough-Georgia Basin ecoregion (Dennehy et al. 2011). Hand pulling is effective for small populations, but for larger infestations, herbicide application at the seedling stage is best (Dennehy et al. 2011). Similar tips for management can be found on the King County government website (Anonymous 2013b). Alternate answers for the Monte Carlo simulation are both "b."
Impact to Anthropogenic Systems (cities, suburbs, roadways)			
Imp-A1 (Impacts human property, processes, civilization, or safety)	n - mod	0	No evidence.
Imp-A2 (Changes or limits recreational use of an area)	n - mod	0	No evidence.
Imp-A3 (Outcompetes, replaces, or otherwise affects desirable plants and vegetation)	n - high	0	No evidence.
Imp-A4 (Weed status in anthropogenic systems)	b - low	0.1	It easily becomes established in gardens, paved areas, and on walls (Yeo 2004). Occasionally common and weedy in gardens (Salisbury 1961). Prolific garden weed in Belfast (FNI 2013). Grows in wet swales of a roadside in Oregon (OSU Herbarium 2006). But no evidence of control in these types of

Question ID	Answer - Uncertainty	Score	Notes (and references)
			systems. Alternate answers for the Monte Carlo simulation are "c" and "a."
Impact to Production Systems (agriculture, nurseries, forest plantations, orchards, etc.)			
Imp-P1 (Reduces crop/product yield)	n - mod	0	No evidence.
Imp-P2 (Lowers commodity value)	n - high	0	No evidence. It may reduce the forage value of unimproved pastures that occur on hillsides where cultivation is not possible (Alverson 2007).
Imp-P3 (Is it likely to impact trade)	y - mod	0.2	This species is a quarantine pest in the state of Washington, where it cannot be sold or moved within the state (Anonymous 2013b). Furthermore, landowners are required to remove it from their properties (Anonymous 2013b). Because this species can contaminate nursery stock (Anonymous 2013b; Dennehy et al. 2011), it is likely to affect some trade in plants for planting.
Imp-P4 (Reduces the quality or availability of irrigation, or strongly competes with plants for water)	n - mod	0	No evidence.
Imp-P5 (Toxic to animals, including livestock/range animals and poultry)	n - low	0	No evidence that this species or genus (Burrows and Tyrl 2001) is toxic.
Imp-P6 (Weed status in production systems)	a - low	0	In pasture in Oregon (OSU Herbarium 2006). However, there is no evidence it is considered a weed of production systems. Alternate answers for the Monte Carlo simulation were both "b."
GEOGRAPHIC POTENTIAL			Unless otherwise noted, all evidence below represents point-occurrences obtained from GBIF (2013).
Plant cold hardiness zones			
Geo-Z1 (Zone 1)	n - negl	N/A	No evidence.
Geo-Z2 (Zone 2)	n - negl	N/A	No evidence.
Geo-Z3 (Zone 3)	n - negl	N/A	No evidence.
Geo-Z4 (Zone 4)	n - negl	N/A	No evidence.
Geo-Z5 (Zone 5)	n - high	N/A	Right along interface between zone 5 and 6 in Norway. Assuming “no” since it is not present within zone 5.
Geo-Z6 (Zone 6)	y - negl	N/A	Sweden and Norway.
Geo-Z7 (Zone 7)	y - negl	N/A	Germany, Norway, Spain, OR (USA). Hardy to zone 7 (PFAF 2013).
Geo-Z8 (Zone 8)	y - negl	N/A	France, Spain, OR (USA).
Geo-Z9 (Zone 9)	y - negl	N/A	Spain, Greece, WA (USA).
Geo-Z10 (Zone 10)	n - high	N/A	A few points near edge in San Francisco (USA) and India.
Geo-Z11 (Zone 11)	n - negl	N/A	No evidence.
Geo-Z12 (Zone 12)	n - negl	N/A	No evidence.
Geo-Z13 (Zone 13)	n - negl	N/A	No evidence.
Köppen-Geiger climate classes			
Geo-C1 (Tropical rainforest)	n - negl	N/A	No evidence.
Geo-C2 (Tropical savanna)	n - negl	N/A	No evidence.
Geo-C3 (Steppe)	y - negl	N/A	Spain and Morocco.
Geo-C4 (Desert)	n - high	N/A	Two points in Algeria, one in Egypt. Because this species appears to favor moist sites (Shaw 2013), we are assuming these points are either erroneous or represent occurrences in

Question ID	Answer - Uncertainty	Score	Notes (and references)
			protected microhabitats.
Geo-C5 (Mediterranean)	y - negl	N/A	Portugal, Spain, United States.
Geo-C6 (Humid subtropical)	y - low	N/A	Greece, Pakistan, one point in Turkey, and one point in Azerbaijan.
Geo-C7 (Marine west coast)	y - negl	N/A	United Kingdom and France.
Geo-C8 (Humid cont. warm sum.)	y - mod	N/A	One point in Pakistan and two in Armenia.
Geo-C9 (Humid cont. cool sum.)	y - negl	N/A	Sweden.
Geo-C10 (Subarctic)	y - low	N/A	Norway and Germany.
Geo-C11 (Tundra)	y - low	N/A	Norway.
Geo-C12 (Icecap)	n - negl	N/A	No evidence.
10-inch precipitation bands			
Geo-R1 (0-10 inches; 0-25 cm)	n - high	N/A	Two points in Algeria, one in Egypt. Because this species appears to favor moist sites (Shaw 2013), we are assuming these points are either erroneous or represent occurrences in protected microhabitats.
Geo-R2 (10-20 inches; 25-51 cm)	y - negl	N/A	Spain, Israel, and one point in Azerbaijan.
Geo-R3 (20-30 inches; 51-76 cm)	y - negl	N/A	Germany, Sweden, and France.
Geo-R4 (30-40 inches; 76-102 cm)	y - negl	N/A	France, Belgium, Portugal, Pakistan, and India.
Geo-R5 (40-50 inches; 102-127 cm)	y - negl	N/A	OR (USA), Spain, and Ireland.
Geo-R6 (50-60 inches; 127-152 cm)	y - negl	N/A	WA and OR (USA) and the United Kingdom.
Geo-R7 (60-70 inches; 152-178 cm)	y - negl	N/A	WA (USA) and the United Kingdom.
Geo-R8 (70-80 inches; 178-203 cm)	y - negl	N/A	United Kingdom.
Geo-R9 (80-90 inches; 203-229 cm)	y - negl	N/A	United Kingdom.
Geo-R10 (90-100 inches; 229-254 cm)	y - negl	N/A	United Kingdom.
Geo-R11 (100+ inches; 254+ cm))	y - low	N/A	United Kingdom.
ENTRY POTENTIAL			
Ent-1 (Plant already here)	y - negl	1	Naturalized and spreading in the United States (CISEH 2013; Univ. of California 2013). Also, this species has been collected twice in Canada from roadside habitats (Klinkenberg, 2013; Univ. of Alberta 2013). Cultivated in California (Anonymous 2013a).
Ent-2 (Plant proposed for entry, or entry is imminent)	-	N/A	
Ent-3 (Human value & cultivation/trade status)	-	N/A	Seeds are available on the internet for resale (Plant World Seeds 2013). Available from a nursery in California that will also mail plants (Anonymous 2013a). Has been used for centuries as a diuretic and astringent in Europe, but is less well known in North America (ODA 2013; PFAF 2013). Cultivated (Randall 2012).
Ent-4 (Entry as a contaminant)			

Question ID	Answer - Uncertainty	Score	Notes (and references)
Ent-4a (Plant present in Canada, Mexico, Central America, the Caribbean or China)	-	N/A	
Ent-4b (Contaminant of plant propagative material (except seeds))	-	N/A	
Ent-4c (Contaminant of seeds for planting)	-	N/A	An impurity in agricultural seed (Salisbury 1961).
Ent-4d (Contaminant of ballast water)	-	N/A	
Ent-4e (Contaminant of aquarium plants or other aquarium products)	-	N/A	
Ent-4f (Contaminant of landscape products)	-	N/A	
Ent-4g (Contaminant of containers, packing materials, trade goods, equipment or conveyances)	-	N/A	
Ent-4h (Contaminants of fruit, vegetables, or other products for consumption or processing)	-	N/A	
Ent-4i (Contaminant of some other pathway)	-	N/A	
Ent-5 (Likely to enter through natural dispersal)	-	N/A	

Appendix B. Maryland filter assessment for *Geranium lucidum* L. (Geraniaceae).

Maryland Filter questions	Answer	Instructions/Result	Notes
1. Is the plant a sterile cultivar or used for root stock only? yes OR no	no	Go to question 2	Reproduces by seed (Anonymous 2013b; Dennehy et al. 2011; Van Assche and Vandelook 2006).
2. Is the plant currently cultivated in Maryland? Yes OR no	no	Go to Question 3	
3. What is the species' potential distribution in Maryland? wide OR narrow	wide	Go to question 4	Grows in zones 6-9 in humid continental climates (GBIF 2013). Could potentially grow in any MD physiographic province in moist sites.
4. Does or could the species harm threatened or endangered Maryland species or community types or CITES listed species occurring in MD? yes OR no	yes	**Tier 1**	Because this species forms extensive stands that outcompete early spring wildflowers (ODA 2013), it is likely to impact understory threatened and endangered species. This species is considered a "major threat to the integrity of oak woodland habitats" in the United States (Dennehy et al. 2011).
5. How feasible is control of the species? easy OR difficult			Questions 5 and 6 are not answered because question 4 resulted in a ranking of Tier 1.
6. Is added propagule pressure from sales significantly increasing potential of the species to persist and spread? yes OR no			